The use of FLCs in electro-optical or fully optical components requires either compounds which form tilted or orthogonal smectic phases and are themselves optically active, or the induction of ferroelectric smectic phases by doping compounds which, although forming such smectic phases, are not themselves optically active, with optically active compounds. The desired phase should be stable over the broadest possible temperature range to ensure that the display has a broad operating range.

The individual pixels of an LC display are usually arranged in an x,y matrix formed by the arrangement of a series of electrodes (conductor tracks) along the rows and a series of electrodes along the columns on the upper or lower side of the display. The points of interception of the horizontal (row) electrodes and the vertical (column) electrodes form addressable pixels.

This pixel arrangement is usually referred to as a passive matrix. For addressing, various multiplex schemes have been developed, as described, for example, in Displays 1993, vol. 14, No. 2, pp. 86-93, and Kontakte 1993 (2), pp. 3-14. Passive matrix addressing has the advantage of simpler display production and consequently lower production costs, but the disadvantage that passive addressing can only be carried out line by line, which results in the addressing time for the entire screen with N lines being N times the line addressing time. For usual line addressing times of about 50 microseconds, this means a screen addressing time of about 60 milliseconds in, for example, the HDTV (high definition TV, 1152 lines) standard, i.e. a maximum frame rate of about 16 Hz, too slow for displaying moving images. In addition, display of gray shades is often difficult. At the FLC conference in Brest, France (July 20-24, 1997, see Abstract Book 6th International Conference on Ferroelectric Liquid Crystals, Brest / France), a passive FLC display with digital gray shades was shown by Mizutani et al., in which each of the RGB pixels (RGB = red, green, blue) was divided into sub-pixels, allowing the display of gray shades in digital form through partial switching. Using three basic colors (red, green, blue), N gray shades result in 3^N colors. The disadvantage of this method is the considerable increase in the number of screen drivers necessary and thus in the costs (in the case of the display shown in Brest, three times as many drivers were necessary as in a standard FLC display without digital gray shades).

In so-called active-matrix technology (AMLCD), a nonstructured substrate is usually combined with an active-matrix substrate. An electrically non-linear element, for example a thin-film transistor, is integrated into each pixel of the active-matrix substrate. The non-linear elements can also be diodes, metal-insulator-metal and similar elements, which are advantageously produced by thin-film processes and are described in the relevant literature (see, for example, T. Tsukuda, TFT/LCD: Liquid Crystal Displays Addressed by Thin-Film Transistors, Gordon and Breach 1996, ISBN 2-919875-01-9, and the references cited therein).

Active-matrix LCDs are usually operated with nematic liquid crystals in TN (twisted nematics), ECB (electrically controlled birefringence), VA (vertically aligned) or IPS (in-plane switching) mode. In each case, the active matrix generates an electric field of individual strength on each pixel, producing a change in alignment and thus a change in birefringence, which is in turn visible in polarized light. A severe disadvantage of these processes is the poor video capability, i.e. the excessively slow response times of nematic liquid crystals.

For this and other reasons, liquid-crystal displays based on a combination of ferroelectric liquid-crystal materials and active-matrix elements have been proposed, for example in WO 97/12355 or Ferroelectric 1996, 179, 141-152, W.J.A.M. Hartmann (IEEE Trans. Electron. Devices 1989, 36 (9; Pt. 1), 1895-9, and Dissertation, Eindhoven, The Netherlands, 1990).

Hartmann used a combination of the so-called “quasi-bookshelf geometry” (QBG) of an FLC and a TFT (thin-film transistor) active matrix to simultaneously achieve high response speed, gray shades and high transmission. However, the QBG is not stable over a broad temperature range, since the temperature dependence of the smectic layer thickness disrupts or rotates the field-induced layer structure. Moreover, Hartmann utilizes an FLC material having a spontaneous polarization of more than 20 nC/cm^2, which, for pixels having realistic dimensions of, for example, 0.01 mm^2, leads to high electrical charges (at saturation, $Q = 2\,A\,P$, A = pixel area, P = spontaneous polarization). With low-cost amorphous silicon TFTs, for example, these high charges cannot reach the pixel in the course of the opening time of the TFT. For these reasons, this technology has not been pursued any further to date.

While Hartmann utilizes the charge-controlled bistability to display a virtually continuous gray scale, Nito et al. have suggested a monostable FLC geometry (Journal of the SID, 1/2, 1993, pp. 163-169) in which the FLC material is aligned by means of relatively high voltages such that only a single stable position results from which a number of intermediate states are generated by application of an electric field via a thin-film transistor. These intermediate states correspond to a number of different brightness values (gray shades) when the cell geometry is matched between crossed polarizers.

The disadvantage of the paper by Nito et al. is the occurrence of a streaky texture which limits the contrast and brightness of this cell (see fig. 8 of the abovementioned citation). While it is possible to correct the disadvantageous streaky texture by treatment with a high electric voltage (20-50 V) in the nematic or cholesteric phase (see page 168 of the abovementioned citation), such a field treatment is unsuitable for mass production of screens and usually does not result in temperature-stable textures either. Furthermore, this method produces switching only in an angle range of up to a maximum of once the tint angle, which is about 22° in the case of the material used by Nito et al. (cf. p. 165, fig. 6) and thus produces a maximum transmission of only 50% of the transmission of two parallel polarizers.

The object of the present invention is to provide a preferably chiral smectic active-matrix liquid-crystal display, containing a preferably chiral smectic liquid-crystal mixture, where the liquid-crystal mixture makes it possible to achieve a very high maximum transmission and a very high contrast and a constant threshold voltage over a broad temperature range.

In particular, a ferroelectric active-matrix liquid-crystal display containing a ferroelectric liquid-crystal mixture is to be provided where the liquid-crystal mixture assumes a monostable position, but without forming any streaky texture, is temperature-stable and makes it possible to achieve a very high maximum transmission and a very high contrast and a constant threshold voltage over a broad temperature range.

This object is achieved according to the invention by a chiral smectic active-matrix display containing a liquid-crystal layer having a tilt angle which is virtually constant over a broad temperature range and a virtually